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Peculiarities of radiative recombination in BeMgZnSe/ZnCdSe injection lasers

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Introduction

The wide band-gap II–IV compounds are considered to be most suitable for manufacturing light emitting diodes (LED) and lasers emitting in a short wavelength range of visible spectrum. Now the utmost interest to such lasers is related to a potential opportunity for creation large-color-screen projection television. Recently, due to the relatively fast progress in the improvement of the structural properties of (Mg,Zn,Cd)(S,Se) heterostructures several groups have reported on lasing both at low [1, 2] and room temperature (RT) [3]. But short lifetime of injection blue-green lasers at RT still limits their commercial application [4].

In this paper we report on study of the main characteristics of RT injection lasers based on BeMgZnSe/ZnCdSe separated confinement heterostructure (SCH).

1 Experimental

The laser BeMgZnSe/ZnCdSe SCH investigated was grown by molecular beam epitaxy (MBE) pseudomorphically to a GaAs (001) substrate at substrate temperature of 270–280 °C. The MBE growth and composition control of Be-chalcogenides based heterostructures have been published elsewhere [5]. The active region of the laser diode structure contains a (10 Å-$Be_{0.05}Zn_{0.95}Se$/15 Å-ZnSe)$_{82}$ superlattice (SL) waveguide lattice-matched to GaAs as a whole, centered with a 2.6 ML-CdSe/10 nm-ZnSe nanostructure. Details of structural and optical characteristics of the active region have been given elsewhere [6]. The structure also involves around 1 μm-thick wider bandgap n- and p-$Be_{0.05}Mg_{0.06}Zn_{0.91}Se$ cladding layers, doped with iodine and nitrogen, respectively, as well as a top ZnSe/BeTe:N modulation doped graded SL capped with a 10 nm-BeTe layer for the low-resisitvity ohmic contact fabrication.

Laser samples of 20 μm-wide stripe geometry were investigated. The lasers were pumped by pulsed current (0.2–2.0 μs pulse duration, 50–1000 Hz repetition frequency). All experiments were carried out at RT.

2 Results and discussion

The dependence of the threshold current density (J_{th}) versus output optical losses is shown in Fig. 1. As follows from it, J_{th} is characterized by an abrupt growth with increasing the losses. The similar drastic increase in J_{th} has been observed earlier and is typical for SCH with quantum well [7].

Electroluminescence (EL) spectra of experimental sample at different pumping currents are also presented in Fig. 1. As is seen, the position of the EL peak is shifted slowly in

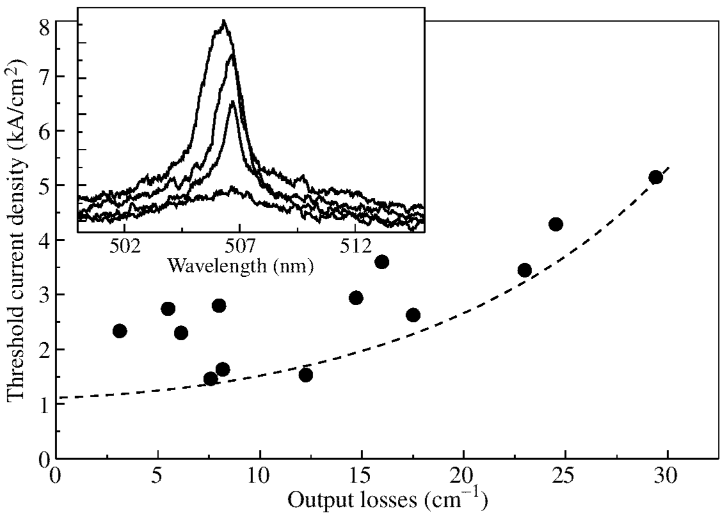

Fig. 1. Threshold current density as a function of output optical losses. Electroluminescence spectra of experimental sample at different pumping current ($0.98I_{\rm th}$, $I_{\rm th}$=265 mA, $1.1I_{\rm th}$, $1.5I_{\rm th}$) are shown in the insert.

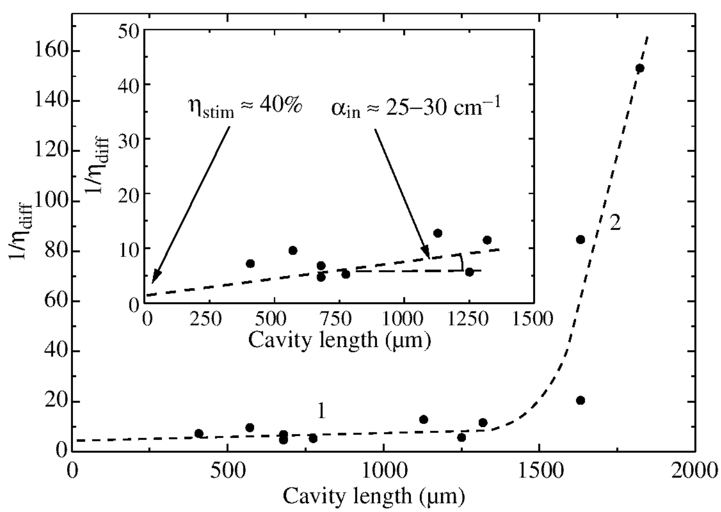

Fig. 2. Inverse differential quantum efficiency of stimulated emission vs laser cavity length.

the short-wavelength direction with increasing the pumping current. It may be attributed to rising an inversion level in the structure.

To determinate the internal quantum efficiency of stimulated emission ($\eta_{\rm stim}$) and the internal cavity losses ($\alpha_{\rm in}$) the differential quantum efficiency — $\eta_{\rm diff}$ (DQE) was studied. We should note that despite the known structural imperfection of the studied heterostructure (stacking fault density is in excess of 10^6 cm^{-2}) the $\eta_{\rm diff}$ as high as 21% per both facets has been obtained. The cavity length dependence of the inverse differential quantum efficiency of the stimulated emission is plotted using experimental data (see Fig. 2).

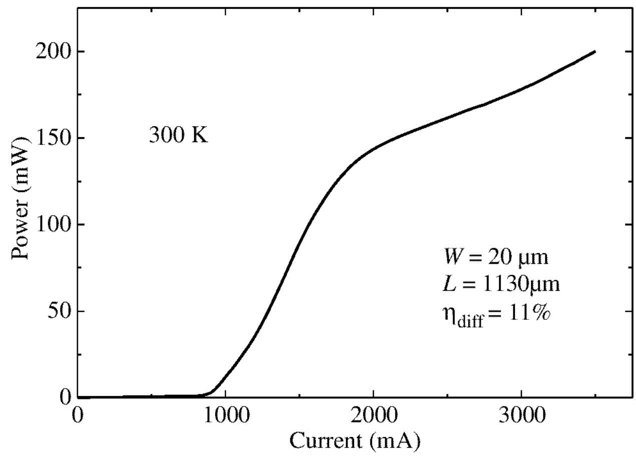

Fig. 3. Light-current characteristic of BeMgZnSe/ZnCdSe laser in quasi-CW regime.

It should be noted that the internal quantum efficiency of stimulated emission is limited by the value of 40%. The rest 60% of emitted photons contribute to a spontaneous recombination. It may be explained by inhomogeneous CdSe-based active region. As follows from Fig. 2 (slope 1), the intrinsic cavity losses reach the value of $25 \div 30$ cm^{-1}, which can obviously be lowered by an optimization of the waveguide geometry (e.g. using wider band-gap emitter). Increasing cavity length (slope 2) up to 1500 μm leads to drastic fall of the DQE (and respectively to rising the inverse DQE). We attribute it with the micro- and especially macro-defects which began to be significant in long lasers.

Using the value of α_{in} and the plot from Fig. 1 allow us to estimate the transparency current density. It has been found to be as high as $\approx$1 kA/cm^2. It can be supposed that improvement both the composition and the uniformity of active region will significantly reduce this value.

In spite of the rather high threshold current density and significant internal cavity losses we succeed in obtaining the quasi-CW laser operation. In that measurements the samples were bonded stripe down to the cooper using indium solder. The light output power reaches 200 mW per facet (Fig. 3), which is the record value ever reported for BeMgZnSe/ZnCdSe blue-green lasers.

No reflecting materials to cover laser mirrors were used. Pumping current pulse had a 2 μs duration and a 1 kHz repetition frequency. The saturation of light-current characteristic under the high pumping current may be attributed to the heating of the active region and neighboring layers.

3 Conclusions

EL study of the BeMgZnSe/ZnCdSe injection laser heterostructure has been performed. The RT threshold current density of $\approx$1.4 kA/cm^2 has been obtained at the lasing wavelength of 506 nm. Maximal value of the differential quantum efficiency achieved is 21% per both facets. RT light output power as high as 200 mW per facet at quasi-CW operation has been demonstrated. Potential opportunities for laser characteristics improvement in such heterostructures have been shown.

Acknowledgements

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References

[1] M. A. Haase, J. Qiu, J. M. DePuydt, and H. Cheng, *Appl. Phys. Lett.* **59**, 1272 (1991).

[2] H. Jeon, J. Ding, A. V. Nurmikko, W. Xie, D. C. Grillo, M. Kobayashi, R. L. Gunshor, G. C. Hua, and N. Otsuka, *Appl. Phys. Lett.* **60**, 2045 (1992).

[3] H. Jeon, J. Ding, A. V. Nurmikko, H. Luo, N. Samarth, J. K. Furdyna, W. A. Bonner, and R. E. Nahory, *Appl. Phys. Lett.* **57**, 2413 (1990).

[4] M. Kato, H. Noguchi, M. Nagai, H. Okuyama, S. Kijima and A. Ishibashi, *Electron. Lett.* **34**, 282 (1998).

[5] A. Waag, F. Fischer, K. Schull, T. Baron, H. -J. Lugauer, Th. Litz, U. Zehnder, W. Ossau, T. Gerhardt, M. Keim, G. Reuscher, and G. Landwehr, *Appl. Phys. Lett.* **70**, 280 (1997).

[6] S .V. Ivanov, A. A. Toropov, S. V. Sorokin, T. V. Shubina, I. V. Sedova, A. A. Sitnikova, P. S. Kop’ev, Zh. I. Alferov, H. -J. Lugauer, G. Reuscher, M. Keim, F. Fischer, A. Waag, G. Landwehr, *Appl. Phys. Lett.* **74**, 498 (1999).

[7] S. V. Zaitsev, N. Yu. Gordeev, V. M. Ustinov, A. E. Zhukov, A. Yu. Egorov, M. V. Maksimov, A. F. Tsasul’nikov, N. N. Ledentsov, P. S. Kop’ev, and Zh. I. Alferov, *Semiconductors* **31**, 539 (1997).